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Art I.—*The Geology of Phillip Island.*

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Abstract.

Phillip Island, which lies across the mouth of Western Port Bay, consists of a large central island, to which is tied a number of smaller islands at both its south-eastern and south-western extremities. It represents the south-eastern interfluve of the river that was drowned to form Western Port Bay. The land slopes gently northwards, and there are few permanent streams. High cliffs occur along the exposed southern coast, while the low northern coastline, in the shelter of Western Port Bay, is prograding. The island consists essentially of a number of flows of Tertiary Older Volcanic basalts, intercalated with thick beds of ochreous red tuff and agglomerate, and overlying Jurassic and Palaeozoic sediments and Palaeozoic granites.

Introduction.

Phillip Island, which lies across the mouth of Western Port Bay, is 13 miles long and $5\frac{1}{2}$ miles wide at its widest point. It has an area of about 60 square miles. On the eastern side it is separated from the San Remo Peninsula by the narrow Eastern Passage, which is from $\frac{1}{4}$ to $\frac{3}{4}$ of a mile wide, and has a maximum depth of about 30 feet. On the western side it is separated from the Mornington Peninsula by the Western Passage, which is from $2\frac{1}{2}$ to 6 miles wide, and has a maximum depth of 90 feet. These two channels separating the island from the mainland are the drowned valleys of streams which were either overdeepened during a low sea-level period of the Pleistocene Ice Age or submerged as a result of subsidence during the Quaternary. The island represents the southern interfluve of the old Western Port River. The tidal range at Cowes, on the northern coast of the island, varies from $7\frac{1}{2}$ feet at neap tides to 12 feet at spring tides, and the tidal race through the Passages develops a maximum velocity of 6 miles an hour.

Composite Structure.

As shown in fig. 1, Phillip Island is a composite island. It consists of a large central island, to which is tied a number of smaller islands.

The narrow south-western extremity of the present island consists of two small tied islands, here called Phelan's Island and Summerland's Island, and The Knobby. Phelan's Island and Summerland's Island are joined to the main island by a Y-shaped

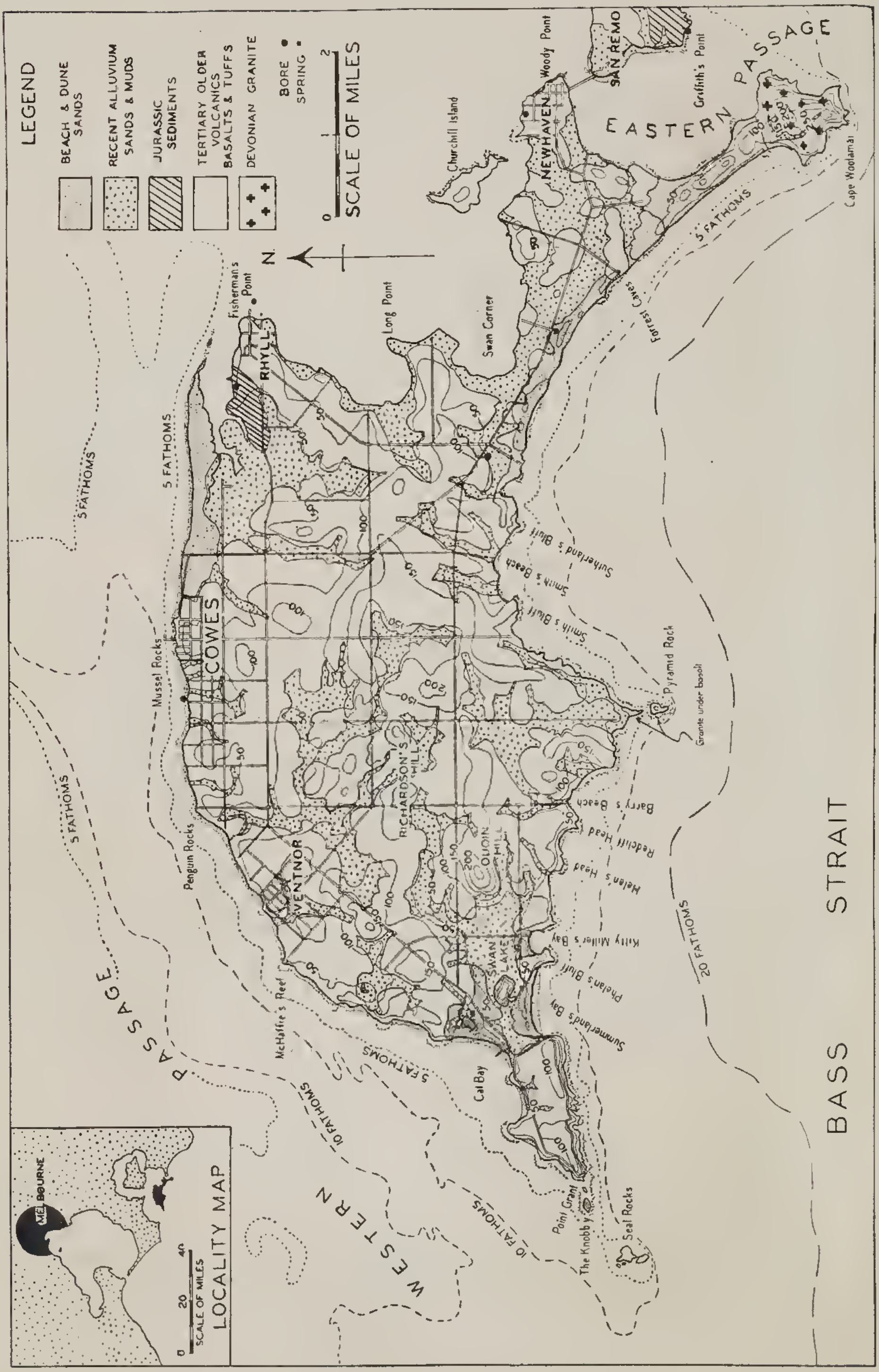
LEGEND
BEACH & DUNE SANDS
RECENT ALLUVIUM SANDS & MUDS
JURASSIC SEDIMENTS
TERTIARY OLDER VOLCANICS BASALTS & TUFFS
DEVONIAN GRANITE
BORE
SPRING
SCALE OF MILES
N
LOCALITY MAP
MELBOURNE
SCALE OF MILES
COWES
RHYLL
NEWHAVEN
SAN REMO
VENTNOR
RICHARDSON'S HILL
OLIVIN HILL
SWAN LAKE
Fisherman's Point
Long Point
Swan Corner
Churchill Island
Woody Point
Griffith's Point
Cape Woolamai
Forrest Caves
Sutherland's Bluff
Smith's Beach
Smith's Bluff
Pyramid Rock
Granite under basalt
Barry's Beach
Redcliff Head
Helen's Head
Kitty Miller's Bay
Phelan's Bluff
Summerland's Bay
Seal Rocks
The Knobby
Point Grant
Cat Bay
McHaffie's Reef
Penguin Rocks
Mussel Rocks
EASTERN PASSAGE
WESTERN PASSAGE
BASS STRAIT
5 FATHOMS
10 FATHOMS
20 FATHOMS

Fig. 1.

tombolo which encloses the partly silted-up fresh-water lagoon of Swan Lake. The Knobby is connected to Summerland's Island by a storm-wave platform that is covered at high tide (Pl. I., fig. 1). About ½ mile to sea, south-west from the Knobby, is a further small island, Seal Rocks (Pl. I., fig. 1). The submarine contours show that it is an integral member of this group of small islands (fig. 1). They are all composed of a series of basalt flows from 20 to 30 feet thick, separated by thin red beds of tuff or weathered basalt (flow tops) along which erosion is concentrated. The lava-flows lie almost horizontal, but the surface of Summerland's Island slopes evenly to the north-west. This series of islands is part of the ridge forming the south-eastern interfluve of the old Western Port River, and the passages between them represent the valleys of small streams tributary to this river. The valleys between Phelan's Island, Summerland's Island, and the main island were first drowned, and then silted up, following the growth of bars across both ends of the channel. The valley between The Knobby and Summerland's Island was left as a low level tract more subject to wave erosion than the higher land to the north-east and south-west. Erosion was concentrated along a red band between the tide levels.

The valley between Seal Rocks and The Knobby is too deeply drowned to permit the growth of spits in such exposed water.

The narrow south-eastern extremity of Phillip Island also consists of a group of small islands tied to one another and to the main island. The most prominent of these tied islands is that formed by the Cape Woolamai granite stock which is linked to the main island by a tie-bar ½ mile wide, carrying sand dunes over 100 feet high (Hills, 1940, p. 229). The inner tied islands are rounded tops of low basaltic hills that rise only 50 feet above sea-level, and represent the higher land between a series of small valleys, some of which were tributary to the Eastern Passage, and some to the drowned Western Port river system.

Topography.

The island has a gently undulating surface, with a general slope to the north, so that whereas the cliffs along the southern coast rise to heights of 150 feet, those along the northern coast are only about 20 feet high. The highest point of the island, apart from Cape Woolamai (300 feet), is Quoin Hill (250 feet), a volcanic plug about 1 mile north-east of Swan Lake. Only four other points, Black Hill on the Ventnor-Knobby road, Richardson Hill in the centre of the island, the adjacent hill in allotment 54, and the hill to the south-east of Quoin Hill rise to 200 feet above sea level. A water parting extends from Quoin Hill to Rhyll.

In the interior of the island, the valleys are shallow swampy depressions trending chiefly to the north or north-west (fig. 1). Near the coast, the valleys become more pronounced, and the valley slopes are sometimes steep, particularly along the south coast. The only permanent stream, the Native Dog Creek, is short and flows into Bass Strait between Helen's Head and Redcliff Head, through a gorge about 150 feet deep.

Water Supply.

Water supply is a serious problem on the island. The rainfall is about 30 inches a year, distributed as shown in Table I.

Table 1.—Average Monthly Rainfall.

	Points.
January	194
February	154
March	247
April	258
May	292
June	320
July	280
August	287
September	287
October	262
November	218
December	206

Potable water is available from shallow wells along the backshore near Cowes township, and most of the local supply is pumped from these wells. The water lies at depths of from 5 to 10 feet, and the water level fluctuates with the tides, owing to the banking up of the seepage at high tides. The water is hard and somewhat saline as is indicated by the analyses Nos. 1 and 2, in Table 2, which were supplied by the courtesy of the Shire Secretary.

In the interior of the island, water is obtained from a number of wells and bores between 50 and 100 feet deep. The water is suitable for stock, but too mineralised for human consumption (Table 2, No. 4). It seeps down the columnar joints of the basalts and accumulates at the base of the basalt flows where they overlie more or less impervious tuff beds.

Springs occur at several localities. A spring of fresh water occurs on the northern side of the high sand dunes, in the reserve between allotments 148 and 151, in the narrow neck of land south of Swan Corner. The dunes overlie a thick bed of tuff, the surface of which slopes to the north. Rain water apparently percolates inland along this surface. Springs of mineralised water occur on the northern side of the Cape Woolamai granite, where the water has penetrated joint planes in the granite, and also close to Cape Woolamai itself (Blandowski, 1857, p. 56). Summerland's House in the south-west of the island obtains much of its water from a spring that issues on the northern side of the tie-bar joining Summerland's Island to the main island. Mr. V. G. Anderson has kindly supplied an analysis of the water of this spring (Table 2, No. 3).

TABLE 2.—ANALYSIS OF WELL AND SPRING WATER, PHILLIP ISLAND.
(mg. per litre.)

	1	2	3	4
Ca	n.d.	n.d.	113	69
Mg	n.d.	n.d.	30	133
Na, K	70	45	136	819
Cl	100	65	234	1249
SO_4	n.d.	n.d.	18	65
HCO_3	n.d.	n.d.	478	355
NO_3	.04	.86	.9	
SiO_2	n.d.	n.d.	14	
Al_2O_3	n.d.	n.d.	4	
Fe_2O_3	n.d.	n.d.		11
Total Solids ..	470	340	1027.9	2701

1. Mathew's Well, Cowes, March, 1937.
2. University Camp Well, Cowes, March, 1937.
3. Water from Summerland's Spring, February, 1934.
4. Water at 117 ft., and rising to 100 ft., in Bore 8, allot. 13. (Rec. Boring Oper., 1926, p. 60).

The Coastlines.

The northern and southern coastlines present a striking contrast, partly owing to the marked difference in the strength of wave attack to which they are subjected, and partly owing to the northerly slope of the surface of the island, which greatly reduces the cliff height on the northern side.

THE SOUTHERN COASTLINE.

The southern coastline is exposed to the full violence of south-westerly gales sweeping across Bass Strait. It forms two large concave arcs, one on either side of the promontory leading out to Pyramid Rock, and consists of three sections of unequal length.

The western section, which is the longest, extends from The Knobby to near Sutherland's Bluff, where only a narrow neck of land, $\frac{3}{4}$ mile wide, separates Swan Corner from Bass Strait. This section consists of steep to sheer cliffs, 50 to 150 feet high (Pl. II., fig. 1), broken at irregular intervals by short stretches of sandy beach. The cliffs are cut in basalt and in thick beds of tuff and agglomerate. The steeper cliffs are cut in the basalts and as many as five successive flows of basalt, more or less horizontal, are exposed in the cliff faces, and stormwave platforms at their bases (Pl. I., fig. 1). In places, the uppermost lava-flow has been so eroded as to form an amphitheatre-like depression in the cliff tops (Pl. I., fig. 6). These depressions are not related to drainage lines, and it is difficult to explain their origin.

The almost vertical black cliffs in the basalt contrast strongly with the higher, less steep cliffs in the bright red-brown tuffs and agglomerate. The tuffs and agglomerates only occur at intervals—namely, at Phelan's Bluff, Redcliff Head, Smith's Bluff, Sutherland's Bluff, and at Forrest Caves and the unnamed bluff west of it. At each locality the tuff or agglomerate overlies more resistant basalt flows, which, at Phelan's Bluff and Redcliff Head, form the base of the cliffs for 10 to 20 feet above high tide level. At Phelan's Bluff, the tuff has been cut back so far that it is now beyond the reach of all but the largest waves and is faced with a boulder beach. The resulting double storm-wave platform at first sight suggests a recent coastal emergence of 14 feet (Pl. II., fig. 3).

All the headlands, and any straight sections of cliffs are fronted by storm-wave platforms (Edwards, 1941). These become narrow on the sides of the headlands, and in the smaller inlets they give place to steep boulder beaches, while in the larger inlets they give place to sandy beaches. The platforms are covered at high tide. They tend to be widest where the cliffs are relatively low, and grow narrower as the cliff height increases. The widest platforms are in the vicinity of Smith's Beach, where they are up to 300 feet wide. The surface of a platform frequently coincides with the top of a horizontal basalt flow (Pl. I., figs. 3 and 4). The tops of the flows are commonly marked by a red band of decomposed rock or tuff, from a few inches to a foot or more in thickness. The red band is less resistant to wave attack than the overlying columnar basalt, which is readily sapped. The surface of the resulting platform is generally level (Pl. I., fig. 4), but it sometimes shows an abrupt "step-up" in level (Pl. I., figs. 1, 4). This results from the columnar structure of the basalt flow above the red band. The basalt generally consists of an upper layer of columns with closely spaced horizontal joints and a base of broad stumpy columns with few horizontal joints (Pl. I., fig. 3). The junction of the two sets is a plane of weakness, and the wave attack may be more effective in eroding the upper layer of closely jointed columns than in sapping the whole thickness of the flow. Where this has happened, the platform "steps up" the height of the lower columns (Pl. I., fig. 4). At an advanced stage of the erosion of such a "step up," only isolated individual columns remain, rather like bollards, on the surface of the platforms (Pl. I., fig. 5).

Residuals of the upper flow sometimes remain as rock stacks on the storm-wave platforms (Pl. I., figs. 2, 6). Pyramid Rock, at the midpoint of this western section of the southern coast, is a rock stack of residual basalt columns, surrounded by a "skirt" of scree, on an irregular platform of pinkish granite (Pl. II., figs. 1, 2). The granite platform is separated from the main island by a narrow channel formed along a master joint.

The surfaces of the storm-wave platforms are relatively smooth where they retain a veneer of the red band (Pl. I., fig. 4). Where the red band has been stripped completely from the platform, its surface is usually grooved by a network of gutterways which follow the columnar joints of the basalt. The basalt adjacent to the joints shows apparent pseudo-flow structure parallel to the jointing. This is an effect of directed attrition by sand and similar fine material swept along the gutterways.

Some platforms show sloping surfaces and abrupt changes in level where they are cut in gently dipping basalt flows of different hardness, or where, as at the eastern end of Smith's Beach, they intersect a sloping bed of silicified gravel intercalated with the basalts. Pot holes, containing more or less spherical pebbles, are sometimes present.

Some platforms show a well-defined "rampart" at their seaward edge, but others remain uniformly level right to the edge (Pl. I., figs. 1, 2). The seaward face or "nip" (Edwards, 1941) is steep to vertical, though sometimes bevelled at the top.

The line of cliffs is broken at Summerland's Bay and at Kitty Miller's Bay by stretches of beach, backed by sand dunes up to 50 feet high. These cap the tie bars joining Summerland's Island and Phelan's Island to the main island. At the head of Kitty Miller's Bay, the dunes have buried a boulder beach rising for 15 to 20 feet above high-tide level.

Small bay-head beaches occur in the embayments near Helen's Head, at the mouth of Native Dog Creek (Barry's Beach), and at a few other points. The cliff line is otherwise unbroken as far as Smith's Beach, where there is a long stretch of beach with dunes accumulating on sloping cliffs of weathered basalt overlain by laterised tuffs. East of this point the proportion of beach to cliffs and storm-wave platforms increases, until beyond Forrest Caves the transition to the second section of the coastline is complete.

The second section of the southern coastline extends from Forrest Caves to the beginning of the granite cliffs near Cape Woolamai. It consists of a sandy beach, with occasional outcrops of basalt in the shore platform, and is backed by cliffs cut in sand dunes that rise to 100 feet above sea-level, and form the tie-bar connecting the tied islands to the main island. The dunes are migrating inland. Forrest Caves are two small caves about 10 feet high, cut in the face of a storm-wave platform of laterised tuff. Their roofs have partly collapsed, and they are submerged at high tide.

The third and most rugged section of the coast consists of the granite cliffs in the vicinity of Cape Woolamai. The tilt of the surface of the granitic stock at 5° to the north (Edwards, 1942) results in an increase of cliff height southwards, until at Cape Woolamai the cliffs are about 250 feet high. The cliffs along the south-western side of the tied island, facing the strongest wave attack (Pl. II., figs. 5, 6) present a bolder and more rugged aspect than those on the south-eastern side (Pl. II., fig. 4). Erosion has driven deeply along the joint planes of the granite, forming gorge-like indentations (Pl. II., fig. 6), sometimes fronted by jagged pyramidal rock stacks, cut off from the cliffs at high tide (Pl. II., fig. 5). Storm-tossed boulders are found along even the highest cliff tops. On the south-eastern side of the tied island the cliffs are very steep, but the headlands are widely spaced between smoothly curved embayments, and the shallow bayheads are backed by a narrow, shelving beach (Pl. II., fig. 4). There are no storm-wave platforms along this section of the coast, presumably because the rocks are too hard to permit any distinctive low-tide erosion (Edwards, 1941).

Proceeding northwards along the Eastern Passage, the height of the cliffs decreases, until a little north of the old granite quarry and its jetty they give place to smoothly rounded sand dunes (Pl. II., fig. 7), which are migrating northwards along the tie-bar, and occasional outcrops of basalt at sea-level. Still further north, the coast is protected from all wave attack, and the high-tide level is marked by a slight nip, with trees and grasses coming down almost to high water level.

The Northern Coastline.

The northern coastline is largely screened from wave attack by French Island and by the easterly extension of the Mornington Peninsula to Sandy Point. These obstacles prevent the development of large waves under the influence of northerly winds, even during gales. The composite tie-bars and islands at the eastern end of Phillip Island effectively shelter the island from south-easterly winds, and prevent rollers from passing through the Eastern Passage. The broad Western Passage, however, faces directly towards the south-west, and affords an easy passage for waves and rollers coming from this direction. Where these waves impinge on the northern coastline in the vicinity of The Knobby and along the north-western side of Summerland's Island, they have cut steep cliffs in the basalt comparable with those along the southern coast. Further from the mouth of Western Passage the strength of the wave action is reduced by the shallow reefs and banks in the Passage, and the land surface becomes lower. A sandy beach begins at Cat Bay (Pl. III., fig. 3), and extends with only minor breaks almost to Rhyll. Beach cusps are often prominent along the section between Cat Bay and McHaffie's Reef. In the sheltered part of Cat Bay, a sand ridge has formed in front of the cliffs, from which it is separated by a shallow swale (Pl. III., fig. 3), and high dunes have formed along the tie-bar joining Summerland's Island to the main island. Cliffs up to 50 feet high persist from north of Cat Bay jetty to McHaffie's Reef. They are cut chiefly in red tuff or decomposed basalt. The tuff overlies the basalt. Fresh basalt is exposed only below high tide mark at the headlands. Sand has accumulated on top of the cliffs, and is migrating inland. Wind erosion has exposed numerous calcareous concretions and root moulds.

At McHaffie's Reef, vertical cliffs up to 50 feet high occur in sloping beds of red tuff, overlying weathered basalt (Pl. III., fig. 2), and a small storm-wave platform has been cut in the tuff on the northern side of the headland (Pl. III., fig. 1).

North of McHaffie's Reef, the coastline trends about 30°N. of E., so that the south-west waves set obliquely to the shore. Longshore drifting of the sand tends to silt up the creek mouths, and the cliffs, which are reduced to 25 feet in height, are faced by one or two sand ridges along the backshore. Low vertical cliffs recur at Penguin Point, where beds of red tuff come down to sea-level. The northerly dip of these beds causes them to strike across the line of the beach.

Beyond Penguin Point, the coastline trends east. The low sandy cliffs continue behind a widening stretch of sloping sandy beach, with a broad shore platform cut in basalt or tuff showing at low tide. The coast is prograding and the shoreline has advanced about 100 yards from the cliff. According to information received from residents, the advance is about 1 yard a year. The back shore consists of one or more ridges of fixed sand, separated from the old cliff line by a broad swale. The beach slopes steeply between high and low water marks, and at low tide there is a strong issue of seepages a few feet above the low water along almost the whole length of the beach. Three small headlands of red tuff, the Mussel Rocks, break the beach line close to Cowes pier.

East of Cowes pier the waves produced by both south-westerly and north-westerly winds combine to set up long-shore drift to the east, with little or no counter tendency from the shallow and sheltered eastern part of Western Port Bay. The eastward drift has caused the formation of a spit, which is now 3½ miles long and is still building out eastwards (Pl. III., fig. 4). This spit has grown across the mouth of a large bay, silted up into a salt marsh, part of which has been drained (Pl. III., fig. 7). The original coastline is marked by a line of cliffs continuous with the present cliffs facing the Nits near Rhyll, and extending almost to Cowes. The older part of the spit is covered by dunes which carry thick tea-tree scrub, but the eastern end is a bare sand bar (Pl. III., fig. 4). The tip of the spit is exposed only at low tide, for a distance of about 1,000 yards, and is becoming compound. The part of the bay still open behind the spit is largely mangrove swamp.

Prior to the growth of the spit, steep cliffs 50 feet high were cut in Jurassic sediments and Tertiary basalts that outcrop west of Rhyll (Pl. III., fig. 5). Where protected by the spit, these cliffs are weathering to form gentle slopes, but at the north-east corner of the island, where the coastline turns southwards, they are exposed to wave attack and are nearly vertical. The basalt of which they are composed is largely decomposed above high water mark.

South of Fisherman's Point at Rhyll, where the coast is protected from all but occasional small waves, progradation is taking place, and a sandy flat extends out some hundreds of yards from the old cliff line which is now rounded and grassed, to a "nip" about 4 feet high, fronted by a beach a few yards wide (Pl. III., fig. 8). Bores at intervals up to 175 feet out to sea from the jetty show that the original surface of the sea floor has been buried beneath more than 50 feet of muds. The head of the bay between Fisherman's Point and Long Point is partly silted up, and the silting up process extends around Long Point into Swan Corner (Pl. III., fig. 6), which is sheltered by Churchill Island. At low tide, Swan Corner becomes a mud flat with a shallow channel in the centre, but an old cliff line is evidence of past wave attacks. At Newhaven, beyond the shelter of Churchill Island, cliffs develop again, in decomposed basalt, and similar cliffs occur on the north-eastern side of Churchill Island.

General Geology.

Phillip Island consists essentially of a number of flows of Tertiary Older Volcanic basalts, intercalated with beds of red tuff and agglomerate, and overlying Jurassic and Palaeozoic sediments and Palaeozoic granites. Outcrops are largely obscured by soil and alluvium, and near the coast by sand dunes.

The earliest description of the geology is given by Blandowski (1857) in a report on his journey from King's Station to Bass River, Phillip and French Islands. The Woolamai granite has been described by McInerny (1929), but apart from this other geologists have made only passing reference to the island. The south-eastern corner of Phillip Island was mapped by Stirling in 1892, as part of Quarter Sheet 76 SW., and during the present work an incomplete manuscript map of the island by Stanley Hunter was made available to the author by the courtesy of Mr. W. Baragwanath, Director of the Geological Survey of Victoria.

Palaeozoic Sediments.

Although not outcropping on Phillip Island, Palaeozoic sediments have been proved in situ in deep bores at Cowes (Bore No. 2) at a depth of 306 feet below sea-level, and at Rhyll (Bore No. 1) at a depth of 459 feet. Sandstones presumably of

Palaeozoic age were encountered at a depth of 216 feet in Bore No. 8, in allotment 143. Xenoliths of little altered rock, several feet across occur in the granite outcrop opposite Pyramid Rock.

The Palaeozoic sediments must occur in the sea-bed in the vicinity of Cape Woolamai, because boulders of hornfels and indurated sandstone are found on the southern beaches in the vicinity of the granite stock, and similar boulders are found along the south-western cliffs of the granite area, where they have been tossed up by storm waves. It seems likely that these rocks form the sea-bed over a considerable area between Cape Woolamai and Pyramid Rock.

The sediments are probably of Ordovician age, since Ordovician graptolites have been found in boulders of slate near Griffith's Point, on the San Remo Peninsula (Hall, 1904).

Jurassic Sediments.

As noted by Blandowski (1857), Jurassic strata outcrop in the north-eastern corner of the island, in the cliff section facing the Nits, west of Rhyll township (fig. 1). They extend inland for about ¼ mile, and then pass beneath alluvium and Tertiary basalts. The cliff section is about 50 feet high, and excellent exposures are afforded in quarries along the cliff face (Pl. III., fig. 5). The sediments consist of felspathic grits and friable arkose, with a few thin beds of grey and black mudstones. The mudstones contain fragmentary plant remains such as *Alethopteris sp.*, and *Sphenopteris sp.*, sufficient to establish their Jurassic age.

The beds dip southwards, and show gentle fold undulations along the cliff face. Blandowski concluded that these beds underlie the inlet to the north, and estimated their thickness at between 400 and 500 feet. This is borne out by Bore No. 1 in allotment 17, which passed from Jurassic to Palaeozoic strata at a depth of 459 feet below sea-level (Ann. Rept. Dept. Mines, for 1912, p. 137). No other outcrop of Jurassic rocks is known on the island, but the Cowes bore put down at sea-level in the Recreation Reserve, encountered a thickness of 120 feet of Jurassic strata beneath 186 feet of basalts and tuffs. Bore No. 7 at Newhaven reached the Jurassic at a depth of 294 feet in allotment 13 (fig. 1).

Tertiary Sediments.

Thin beds of pre-basaltic gravels, derived from the adjacent granite, occur in the cliffs facing Pyramid Rock, and along the northern margin of the Cape Woolamai granite. Post-basaltic gravels of a similar character cap the basalt flow facing Pyramid Rock, and an inter-basaltic gravel, about 10 feet thick, which has been converted to quartzite, is found at the eastern end of Smith's Beach, where it outcrops as a ridge in the storm-wave platform. Boulders of this quartzite are numerous along the adjacent beaches. The outcrop is crescentic to the south, and dips inwards, indicating that it was deposited in a north-sloping valley in the underlying basalt.

Red gravels, up to 10 feet thick, overlying decomposed basalt, outcrop from beneath the dunes just north of Cat Bay jetty. They resemble the "Red Beds" above Older Volcanic basalts at Stony Point and at Corinella Point, on the western and eastern shores of Western Port.

Recent Sediments.

Alluvium fills most of the shallow valleys on the island, and dune sands are found at intervals along the coast, especially along the tie-bars. Recent sands and gravels are developed where the sheltered portions of the coast are prograding.

Igneous Rocks.

Amphibolites.

Numerous boulders of amphibolite have been washed up in the shingle and boulder beach along the western side of Kitty Miller's Bay (Phelan's Bluff). They may be derived from Pre-Cambrian rocks offshore, but it seems more probable that they are derived from the ballast of the "Speke," which was wrecked off this point in February, 1906.

Granites.

Granites, presumably of Devonian age, outcrop in the south-eastern extremity of the island, at Cape Woolamai, and at Pyramid Rock, midway along the southern coast (fig. 1).

The Woolamai granite is a stock-like body, covering an area of about 4 square miles. The eroded surface of the stock slopes at 5°N. The stock was originally part of the Bass horst, and owes its northward tilt to the fault movements that gave rise to the horst (Edwards, 1942). Good exposures are limited to the cliffs. The rock has been described by McInerny (1929), and its heavy minerals have been listed by Baker (1942). It is the most acid of analysed Victorian granites. It consists of quartz, microperthite and oligoclase, and occasional flakes of biotite. Some of the biotite is altered to chlorite, which accounts for "the intense green colour of the mica" noted by Blandowski (1857, p. 54). The microperthite contains much iron oxide dust, which causes it to appear a pleasing pink in the hand specimen. The rock is relatively coarse-grained, individual crystals averaging about 3 mm. across. It has a high crushing strength (27,100 lb. per sq. in.).

The granite has been quarried for building purposes on the eastern side of the stock, close to water level. It is strongly jointed; in the vicinity of the quarry, one set of master joints strikes N.-S., and dips at 60°E., another strikes E.-W., and dips at 30°S. On the opposite side of the island, this jointing has given rise to pyramidal rock stacks. Along the south-eastern part of the coast, two sets of flat dipping joints, one dipping east and the other west, combine with nearly vertical joints to produce a columnar or " blocky " structure in the cliffs.

Veins and segregations of aplite and pegmatite traverse the granite in places. Crystals of reddish-brown orthoclase an inch or more long are found in vughs in the pegmatites. Xenoliths and segregations of basic minerals are generally absent.

At its northern end, the granite is overlain by thin beds of Tertiary gravels, largely derived from the granite, and by Tertiary basalts, and Recent dunes.

Granite outcrops at the base of Pyramid rock in the cliffs of the main island, where it is overlain by thin grit beds, and by columnar basalt. This outcrop is finer-grained than the Woolamai granite, but is otherwise similar. It contains xenoliths of Palaeozoic sediments ranging up to 3 feet across. The larger xenoliths are practically undigested.

Tertiary Volcanic Rocks.

The Tertiary volcanic rocks consist of flows of basalt of thicknesses ranging from 15 ft. to 90 ft., intercalated with beds of tuff and agglomerate up to 150 feet thick. The tuffaceous material is generally altered to red clay, red ochre, or laterite. The relation of the volcanic rocks to the fault movements that have affected Western Port leaves no doubt that they belong to the Tertiary Older Volcanics, and this is confirmed by the petrological character of the basalts.

Pyroclastic Rocks.

The volume of pyroclastic rocks on Phillip Island appears to equal the volume of lava flows. They are best exposed along the southern coast, between Phelan's Bluff and Forrest Caves. They form prominent red headlands. They show rude stratification, and at Redcliff Head, Smith's Beach, and Forrest Caves, they dip inland at about 5°N. The coarsest agglomerate contains angular fragments of decomposed shaly material several inches across, embedded in red clay. Massive agglomerates grade with decrease in the size of the fragments into beds of ochreous red clay, such as have been found intercalated between the Older Volcanic basalts at Flinders and Korkuperrimul Creek (Jacobson and Scott, 1937). In places, as east of Forrest Caves, the tuff is only partly ironstained, and unstained grey clays are found with hardened red clay in the joints and bedding planes. The soft grey clay contains about 40 per cent. of gibbsite and halloysite, soluble in sulphuric acid. Where this parti-coloured tuff is subject to wave attack, the grey clay is washed away, leaving a coarsely honeycombed cliff face.

At Smith's Beach, red tuff overlying deeply weathered basalt is completely lateritized.

Ochreous red tuff beds outcrop in the vicinity of McHaffie's Reef and at Penguin Rocks. At McHaffie's Reef, and for about 300 yards south of this headland, the tuffs form a gently domed structure which is exposed in section in the cliffs. Presumably these arched tuff beds are part of an old volcanic cone. Some of the tuff is closely spotted with areas of a white clay-like zeolitic substance, apparently halloysite.

At Penguin Rocks, red tuff beds occur which dip to the north, and form an abrupt low cliff crossing the beach almost at right angles. A quarter of a mile to the south-west what are apparently the same beds outcrop in the beach with a southerly dip. Between these two points the red beds can be observed in the cliff section, where they dip eastwards. Presumably these tuffs mark another centre of eruption.

Similar, but lateritized, red beds form the Mussel Rocks near Cowes Jetty and outcrop in the main street; shallow cuttings along the various roads across the island indicate that the tuffs are widespread. In most of the outcrops they can be seen to overlie basalt flows, but at Smith's Beach a basalt flow can be seen in section, filling a valley eroded in the tuffs.

LAVA FLOWS.

Flows of basalt extend over the greater part of the island, but with a few exceptions, such as Quoin Hill, exposures in the interior of the island are poor. The best exposures are along the southern coast between the Knobby and Summerland's Beach, and between Kitty Miller's Bay and Smith's Beach. Along these sections of the coast as many as five successive flows are exposed in section. The individual flows are from 15 to 90 feet thick.

At Pyramid Rock and at the northern end of the Woolamai granite mass, the basalts can be seen overlying the granite bed-rock, but the bore records show that the base of the basalt series lies well below sea-level—near Newhaven it is between 200 and 290 feet below sea-level, while at Cowes it is about 180 feet below. It is probable, therefore, that the granitic outcrops, and the Jurassic outcrop west of Rhyll, represent hills rising above the general level of the pre-basaltic terrain.

The outcropping basalts are all closely similar. They are under-saturated olivine-basalts, chiefly of the Flinders type (Edwards, 1938). Samples from the two flows encountered in the Cowes bore are also of this type. The rock composing Quoin Hill is an olivine-basalt with titaniferous augite, and is of the Mooroodue type. Thin sections in the Geology Department collection include an olivine basalt of the Keilor type. The only other variant encountered is an olivine-basanite, from the bottom of the gorge near the mouth of Native Dog Creek. This rock is very closely allied to the characteristic monchiquites of the Older Volcanic series, except for an unusual richness in analcite.

Zeolites, chiefly gmelinite and chabazite, and sometimes aragonite, abound in the vesicles of some of the flows, particularly near their bases, especially in the vicinity of Smith's Bluff and Sutherland's Bluff.

The only prominent point of eruption is Quoin Hill, an almost conical plug which rises steeply to about 150 feet above the surrounding country. A flow appears to have issued from this centre on its west side.

The only chemical analysis of these basalts is that quoted by Skeats (1909) from Selwyn's Catalogue of Rock Specimens and Minerals in the National Museum, Melbourne, 1868. The analysis, which is a second-grade one, shows a general resemblance to analyses of the Flinders type of basalt but is not typical in that the MgO content of the analysed specimen is unusually high, and the CaO content is lower compared with most Victorian analyses.

DYKES.

Several light-coloured dykes of a mugearitic character have been intruded into the basalts in the storm-wave platform at Point Grant. They are up to 2 feet wide, and fill master joints in the basalt, sometimes projecting as low walls. They sometimes step sideways along joint planes, and then resume their main trend, until they split into several branches a few inches wide, each following a separate joint plane. Some movement has taken place since their intrusion, because one dyke was observed to be slightly faulted. The dykes have chilled margins, with a somewhat coarser central part, showing flow banding. They consist essentially of parallel laths of felspar, too altered for precise determination. Much of it appears to be oligoclase. Ferromagnesian minerals, if originally present, were restricted to the groundmass, but the rock is too altered to reveal them.

Several similar dykes intrude the basalts in the shore platforms between Cat Bay jetty and McHaffie's Reef.

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Description of Plates.

Plate I.

Fig. 1.—The Knobby from Summerland's Island, at low tide. Seal Rocks in the distance.

Fig. 2.—Storm-wave platform with rock stack, cut in horizontal basalt flows, south coast, Summerland's Island, near the blow-hole.

Fig. 3.—Showing the columnar structure of the basalt overlying the "red band" in which the storm-wave platform is cut.

Fig. 4.—Surface of a storm-wave platform cut in a "red band", with a "step up" in the left middle distance.

Fig. 5.—Residual column of basalt with a pedestal of "red band" on a storm-wave platform.

Fig. 6.—Ampitheatre-like depression in cliff-top, Summerland's Island.

Plate II.

Fig. 1.—Basalt cliffs fronted by storm-wave platform, in the vicinity of Pyramid Rock, near high tide. Cape Woolamai on the skyline.

Fig. 2.—Pyramid Rock, consisting of a residual of columnar basalt, surrounded by basaltic screes, on a base of lighter-coloured granite.

Fig. 3.—Phelan's Bluff from Kitty Miller's Bay at high tide. The Bluff consists of thick tuff beds overlying a basalt flow which rises to 14 feet above high-tide level. Storm waves have cut back the overlying tuff, giving rise to a high level storm-wave platform, suggestive of recent emergence.

Fig. 4.—Granite coast on the relatively protected south-eastern side of Cape Woolamai.

Fig. 5.—Granite coast on the exposed south-western side of Cape Woolamai, showing influence of joint planes on the development of rock stacks.

Fig. 6.—Granite coast on the exposed south-western side of Cape Woolamai, showing the influence of the joint planes on the development of gorge-like embayments.

Fig. 7.—Sand dunes growing on the protected coast of the Eastern Passage.

Plate III.

Fig. 1.—Small storm-wave platform cut in red-tuff at McHaffie's Reef.

Fig. 2.—Cliff section through domed tuff beds, at McHaffie's Reef.

Fig. 3.—Dune ridge on the back shore at Cat Bay. Tree-covered dunes fronting Summerland's Island tie-bar in the middle distance, and Quoin Hill on the skyline.

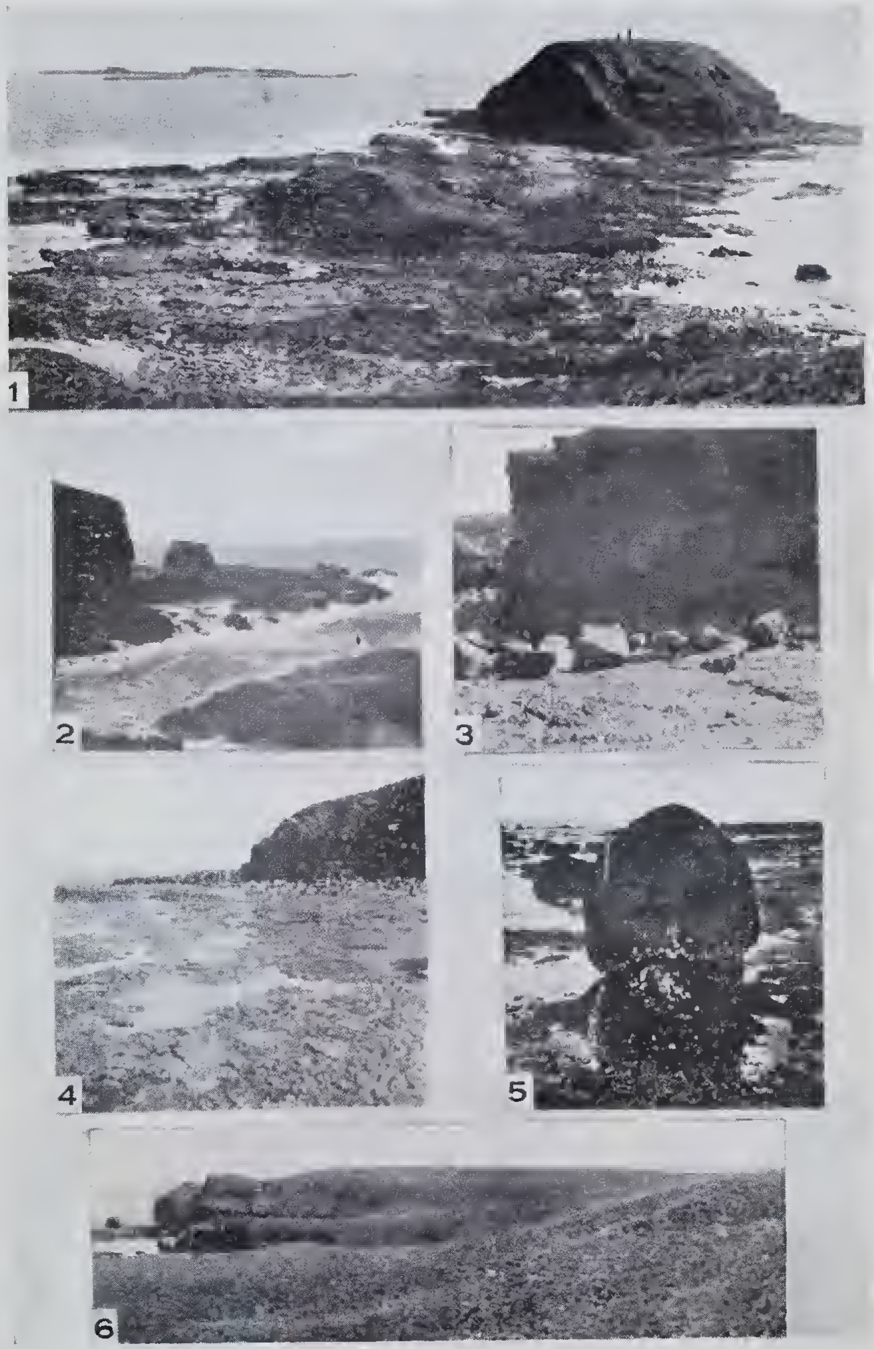
Fig. 4.—End of the spit, fronting Mangrove Swamp, west of Rhyll. French Island on the skyline.

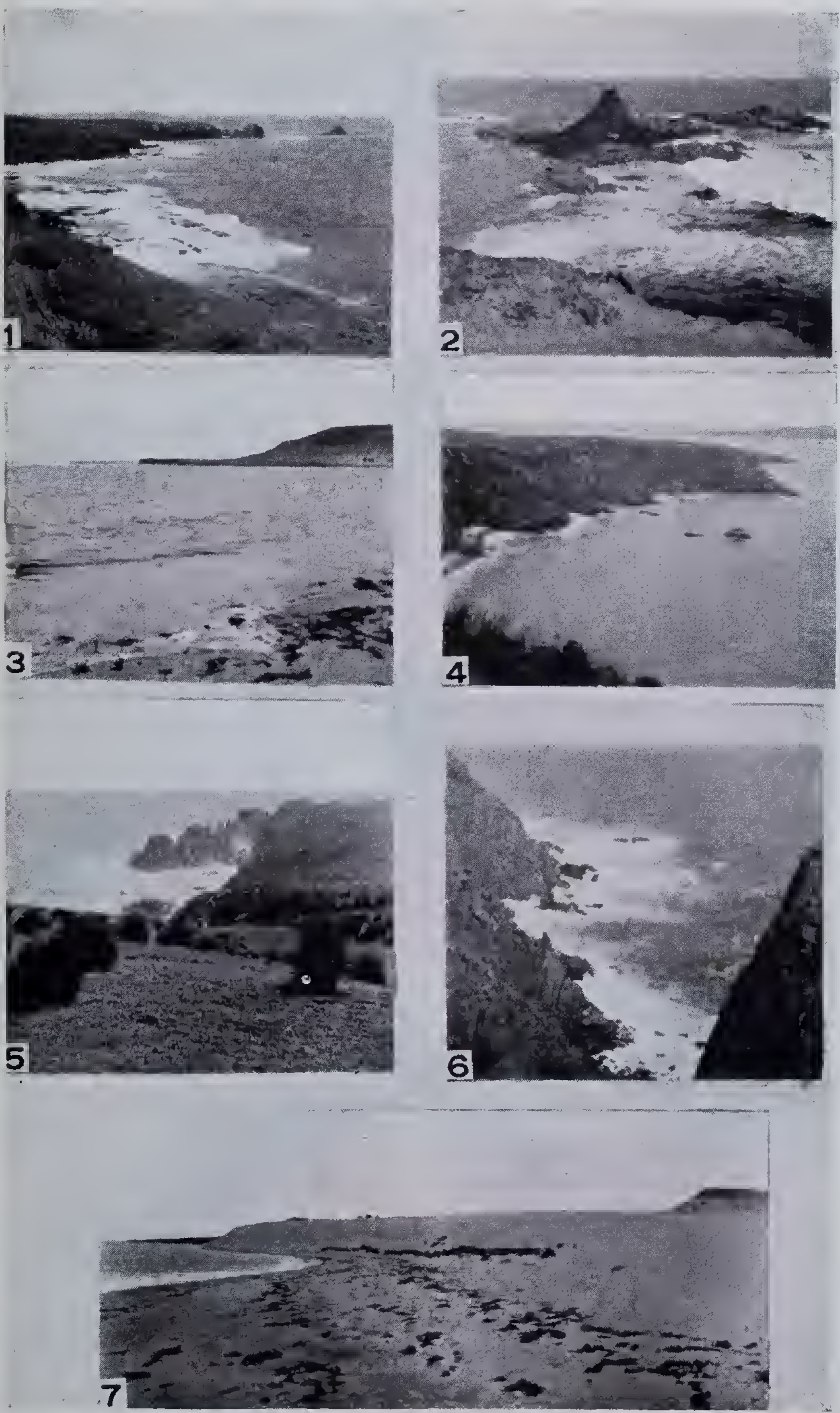
Fig. 5.—Quarry in Jurassic rocks in the old cliffs north-west of Rhyll.

Fig. 6.—Prograded beach on Swan Corner.

Fig. 7.—Silted-up bay behind the spit extending east from Cowes, looking from the top of the old cliff line. The old cliffs can be seen in the distance.

Fig. 8.—Nip cut in prograded land at Rhyll township.



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